COMMENT

RHODODENDRON POISONS THE SOIL, DOESN'T IT?
Chinese whispers become conservation lore

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It's a well-known fact that rhododendrons poison the soil, isn't it? When I first heard it mentioned, in a radio programme, I asked around to find out how and why. Nobody could tell me, though they all knew it was true! Unsettled by the way this meme[1] circulates and proliferates, unquestioned and apparently unverified, and conscious that it seemed to contradict my own observations, I resolved to hunt it down to source.

Here are a few examples of this seemingly authoritative claim, all referring to *Rhododendron ponticum* in Britain:

> "Rhododendron poisons the soil around it so that other plants cannot grow." Plantlife.[2]

> "It produces toxins, and suppresses other plants by poisoning the soil as well as year-round shading." Greenham & Crookham [West Berks.] Conservation Volunteers.[3]

> "Although considered attractive, this belies its true nature which is to shade out native species, leaving an impoverished landscape in its wake. To do this, it has a nasty trick up its sleeve – the roots are actually toxic to other plants! So not only does Rhododendron block out life-giving light, but it poisons the soil as well." Ulster Wildlife Trust.[4]

> "As well as shading large areas to cut out light for other plants to grow, the bush poisons nearby soil with chemicals that kill other species." Jenny Fyall, news.scotsman.com.[5]

> "This [*R. ponticum*] litter remains even after the plant is eradicated and can form a toxic humus layer, which is reported to retard new growth of other plant species for up to seven years." Non-Native Species Secretariat.[6]

> "… as ManicBeancounter[7] notes, it poisons the ground leaving it infertile for other species." Alfred T Mahan.[8]

Before reviewing the published literature that might hold the secret of our 'rhodomeme's' origins, I would like first to consider my own field observations in the light of ecological information that may be unfamiliar to many readers. I will have to introduce some quite challenging concepts and terminology, but each time I stray into territory where incomprehension is likely to cause readers' eyes to glaze over and minds to shut down, I will provide assistance, either as notes or referral to outside sources, in particular my own web pages dedicated to the explanation of mycorrhiza.[9]

Rhododendron infestations may be artificially characterised in numerous ways, according to, for instance: time since introduction, bush size and growth architecture, extent of infestation, density of cover, and environmental impact. For the following discussion two categories will suffice: isolated bushes and total cover.

ISOLATED BUSHES

We can learn a lot from meticulous observation. Walk around a selection of isolated *R. ponticum* bushes and observe the amount of inhibition the adjacent flora has suffered, making comparisons with adjacent rhododendron-free land. Is there any sign of scorched, intoxicated vegetation or local changes in community composition, such as is so conspicuous in places where otters deposit their regular territory markers (spraint) or urinate? In my experience, except where a bush has grown sufficiently to prevent light reaching the ground, no change is apparent.

Apparent. One's evaluation of a community of organisms is governed by one's ability to recognise its components. Familiar trees and wildflowers may be instantly identified, but what about all the grasses, sedges and rushes? If one knows little about obscure mosses or leafy liverworts they will probably not be noticed, because they simply don't register or have to be overlooked because they are unidentifiable.[10] Organisms that live in the deep, dark soil are invisible, whilst many are unseen and overlooked because they are microscopic – microbes (and my identification rule also applies here, with bells on!). A large proportion of the most important components of natural communities are so cryptic that they cannot be detected at all without seeking out DNA sequences that set them apart from other unnoticed or invisible but more conventionally detectable creatures.[11]

Has anyone actually witnessed or detected after the fact (not read about, heard about or presumed) a real change in biodiversity in the vicinity of a single rhododendron? (Under a thicket is a different matter, discussed below.) Given current conclusions we may presume (cautiously and ready for a change of mind in the light of new information) that as long as plants have light they can live in harmony with a rhododendron bush and support the other organisms with which they normally interact and to which they are irrevocably bound in a multitude of ways. The trouble really starts when several of these dense evergreen bushes coalesce to create deep shade in which no green plant can survive. It is at this point that biodiversity impoverishment, above and below ground, with additional deteriorations caused by interrupted feedback loops within groups of interdependent systems, begins and becomes increasingly worse as the invasion intensifies and spreads.

Bearing this in mind, any effects individual rhododendrons have on the vegetation within which they have germinated seem to be a lot less severe than the shading they cause once they have matured, multiplied and formed their invariably dense, year-round closed canopy.

However, this confident conclusion should not depend upon general observation and anecdote alone. It could and should be tested objectively with well-designed field experiments.[12] Fortunately, a certain amount of research has been done, discussed below in the literature review.

TOTAL COVER

Consequences of shading

When *R. ponticum* has become well established, bushes are likely to be contiguous and the site will be colonised to the extent that the vegetation it supports is more or less a rhododendron monoculture. As far as the native flora is concerned, the resultant shading is catastrophic. Because low light levels inhibit and ultimately prevent photosynthesis, few plants can grow beneath continuous rhododendron cover. Ground flora is reduced and then eliminated, and only a few specialists thrive in rhododendron gloom. This is likely to lead to several predictable consequences when rhododendrons are suddenly cleared from the site.

Soil quality

A monoculture of rhododendron produces a huge biomass of litter composed of leaves with thick cuticles that decompose slowly. Such a litter may be impenetrable to the little roots of seedlings.[13] Land favoured by *R. ponticum* is usually acidic and seems to become more so under occupation. Such soils are certainly markedly less hospitable than, say, time-structured woodland brown earths where rapid litter decomposition and turnover and soil stratification are the norm.

Islands & ecological isolation

Local plants are eliminated by continuous rhododendron cover, and the greater the area affected, the farther propagules of replacements must travel in order to recolonise a site. The study of Island Biogeography[14] supplies appropriate models that may clarify the ecology of this problem, for a rhododendron site is analogous to an island in a sea of, for instance, native oak-bluebell woodland. The larger the island, the greater its impact on the landscape and the longer habitat recovery or restoration will take post-rhododendron.

Plants do not grow alone

Not only plants are eliminated as a site becomes colonised by rhododendrons. Other organisms that are intimately bound into the community, dependent upon individual plants, plant species and plant communities for their existence, suffer in tandem.[15] For instance, an estimated 90-95% of all plants on the planet are dependent to a greater (many obligately) or lesser degree upon a community of soil fungi with which they form symbioses in their roots (mycorrhizas). I will concentrate on mycorrhiza because it is what I know about.[16] An author with a different speciality might choose bacterial, nematode[17] or protist[18] communities to illustrate the same points about ecological complexity.

Mycorrhizal fungi provide ecosystems with a range of nutritional and protective services from the local plant:fungus scale to the complex multi-species landscape scale. Mycorrhizal associations occur as several distinct and diverse taxonomic and functional types (*about which more below and also see note 9*), but they are only one multifarious component in a complex of interconnected systems that support all habitats including those vulnerable to rhododendron invasion. If deprived of the mycorrhizas upon which they depended throughout their evolution[19] and still depend for their existence, plant communities collapse, and it is likely that they will take a very(!) long time to recover, length depending on starting point. The post-rhododendron condition is little better than barren soil, so they will have to be built anew, by ecological succession, taking hundreds, perhaps thousands of years to return to their original state.

The fate of mycorrhiza during rhododendron occupation and clearance

Besides massive declines in populations of mycorrhizal fungi, as infestation proceeds land taken over by rhododendrons is likely to experience changes in mycorrhizal type. *Rhododendron* species are, significantly, members of the family Ericaceae, the family that includes heathers and *Vaccinium* ‘berries’. Most inhabit acidic peaty soils and associate with a small number of fungal species in the genera *Oidiodendron* and *Hymenoscyphus*. These ericoid mycorrhizal fungi enable their partners to grow in soils where nitrogen (N) is a limiting nutrient. Peaty soils are rich in N, but because it is tied up in indigestible organic molecules (protein etc.), it is inaccessible to plant roots which, unassisted, can absorb only inorganic nitrate, nitrite and ammonium ions. Ericoid mycorrhizal fungi digest and release peat-bound N by mineralisation, shunting it as inorganic N into the roots of their ericoid plant partners.

There are habitats in Britain that are readily invaded by ericoid mycorrhizal rhododendrons, where non-dominant native ericoid mycorrhizal species grow within a diverse mosaic of others that are ectomycorrhizal and glomalean endomycorrhizal with occasional orchidoid mycorrhizal plants, mycoheterotrophs and mixotrophs. Here we have a perplexing procession of unfamiliar technical words which should indicate that the situation is rather complicated. Correct, and this dynamic complexity plummets when rhododendrons take over. As this ecological simplification proceeds, perplexing scientific words become less and less applicable.

If ericoid mycorrhizal fungi – which have low specificity of association, that is they are not over particular about which plant species they pair up with – are already present at a site, then rhododendron colonisation and bush maturation may be swifter than at another where seedlings need to wait for fungi to arrive on the breeze or inside worms. One might casually observe that the former tends to be the case in parts of the country where rhododendrons are already a serious problem.

Meanwhile, as rhododendron bushes grow, they shade out adjacent plants which results in – as we may now predict, given the fresh knowledge provided above – the demise of their mycorrhizal associates which cannot live in their partners’ absence or in a disintegrating, progressively impoverished community of interdependent species. Remember that there will be several other vital biological systems in every complex ecosystem which might well suffer a similar fate.

The fate of a site after rhododendron occupation and clearance

Let us now consider the natural recolonisation of a post-rhododendron-clearance site. Assuming the desired end result is species rich native moorland, heath or woodland, a suite of particular plants will need to re-establish, their propagules mostly travelling in from beyond the site boundary. Many of them will need to find a safe place within the community to which their evolved adaptations suit them that includes partnership with symbiotic and other helper organisms, usually soil fungi, bacteria etc. Their ‘shopping list’ of essential conditions will be extensive, so simply to arrive as a seed is a recipe for failure. That is the speciality of the pioneers; weeds. Movement of species complexes rather than individuals is a hazardous process that is likely to take a long time,[20] but achieved by working their way gradually inwards from the site margin. A mature native community does not just happen when a site becomes available, it needs to evolve qualitatively and quantitatively from simple to complicated along a development gradient (succession). The first plants to take advantage of the bare site will not be bluebells and oak trees. They are more likely to be rosebay and alder, rushes and gorse. Vigorous invaders such as Japanese knotweed or even *R. ponticum* might also stake a claim, preventing the succession from progressing where they dominate – as they surely do when they get a foothold.

It is fashionable to presume that we can replant woodland and might attempt to do so once rhododendron has been cleared. Since we have little idea what woodland consists of – it's not just a collection trees, shrubs and herbs plus a few unidentifiable mosses and things – what should we plant and how do we get to grow the plants we discover the hard way are not amenable to horticultural methods? The countryside is complicated and inscrutable, certainly not something we can easily rebuild once we have damaged it. Our tree planting efforts compared with native woodland are equivalent to a garden shed in the shadow of Salisbury Cathedral. Simple tree planting produces plantations, not proper woodland.[21]

The plants that arrive first are not particularly dependent upon symbiosis and many are non-mycorrhizal. Pioneers have evolved to thrive without or with minimal fungal assistance. The terminology used to describe this ecological situation is much, much simpler than I used in the mycorrhiza section above, but then, so too would be the entire ecological situation in the early stages of succession. A cleared site populated by opportunistic weeds is more uniform and simpler (plain and boring) than long-established, biodiverse woodland (beautiful and fascinating).

Summary

- As rhododendron encroaches and the native community becomes impoverished, the biodiversity of the flora and soil biota decline in tandem. (Remember there are other groups of organisms vital to ecosystem integrity besides the fungi I happen to have become enthusiastic about.)
- When rhododendron has become a monoculture covering many hectares, we can justifiably suppose that very little remains to represent what was once a dynamic, mycorrhiza-supported, species rich community, other than *R. ponticum*, one or two associated ericoid mycorrhizal fungi and a handful of shade/rhododendron tolerant plants and plucky survivors.
- That is a very poor landscape and a disastrous starting point for its recovery.
- Recolonisation by native flora of an area cleared of rhododendron is more likely to be inhibited by: a) soil rendered inhospitable by *R. ponticum* leaf litter; b) poor nutrient supply and c) low availability of nutrients due to local extinction of the soil community that normally facilitates their mobilisation than by soil 'poisoning'.
- Whether during occupation or after clearance, it would have been better if the rhododendrons had never arrived in the first place.
- If one did not consider the alternative implications of catastrophic reductions in biodiversity as discussed above, one might, influenced by rumour, incorrectly conclude that the soil had been poisoned.

LITERATURE REVIEW

When I set out to investigate this topic my main purpose was to find sources for what I had begun to suspect might be little more than a widely held rumour. If I was going to refute what I thought might be a misconception, I needed to find some evidence from research or reveal a lack thereof.

What I did discover was many, many occurrences of the rumour and very little scientific literature referring to aspects of rhododendron biology such as poison, poisoning, toxin, toxic, intoxication and allelopathy. Scientific sources do not make brazen statements such as, "Rhododendron poisons the soil", but a few have investigated a range of inhibitory physical and chemical influences in this context, including the phenomenon known as allelopathy[22] which, these days, seems not to be taken as seriously as it used to be.

After assiduous searching and cross-referencing I discovered that the literature on this subject is very restricted and I have so far found nothing to support claims that "Rhododendron poisons the soil" or that it has any allelopathic effect on adjacent vegetation that should give us cause for alarm.

In fact only three papers,[23] by various members of an international research collaboration based at Virginia Polytechnic Institute, U.S.A., provide any indication of the source of what I conclude is an old wives' tale, now rampant in Britain:

> 1. Nilsen, E.T. *et al.* (1999). Inhibition of seedling survival under *Rhododendron maximum* (Ericaceae): could allelopathy be a cause? *American Journal of Botany*, 86(11): 1597–1605.[24]

This is the most frequently cited paper about a project conducted both in laboratory and in the field using highly manipulative methodology (i.e. creating artificial experimental conditions for assay rather then evaluating ecological processes without intervention). The research took place in the U.S.A. at a site dominated by *R. maximum*. The research team reported, "… our study did not discern a significant allelopathic influence in the field …" of *R. maximum* and, "The reduced growth rate of seedlings growing in the +*R.m.* sites is most likely due to reduced resource (light) availability." The hypothesis that allelopathy could be the cause of seedling inhibition by *R. maximum* was not proven. Thus Nilsen *et al.* stressed that light could be the limiting factor.

> 2. Clinton, B.D. & Vose, J.M. (1996). Effects of *Rhododendron maximum* L. on *Acer rubrum* L. seedling establishment. *Castanea*, 61:1, 38-45.[25]

This experiment considered only one canopy tree species, the maple *Acer rubrum*. One major conclusion was that seedlings found germination difficult on the forest floor, i.e. on litter, which is deep slow decomposing and generally inhospitable under rhododendron. Linton & Vose failed to demonstrate allelopathy and concluded that, "Low soil moisture beneath *R. maximum* is a potential regulating mechanism, but allelopathy, nutrient limitations, or both are equally plausible mechanisms. Future studies should separate the effects of moisture, nutrients, and allelopathy on germination and establishment."

> 3. Lei, T.T. *et al.* (2002). Effects of *Rhododendron maximum* Thickets on Tree Seed Dispersal, Seedling Morphology, and Survivorship. *Int. J Plant Sci.* 163:6, 991–1000.[26]

This is another field trial in which seedling inhibition under *R. maximum* thickets was demonstrated but concludes, "In addition to light limitation seedling establishment under an intact forest *may be* affected by competition for soil moisture and nutrients, allelopathy, lack of appropriate mycorrhizae, predation, and pathogens" (my emphasis).

Additionally, Offwell Woodland & Wildlife Trust provide this intriguing information on their website.

> Inhibitory Effects of Rhododendron
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> There is some evidence for allelopathic interactions (the production of adverse effects on other species) between Rhododendron and other plants. This may include the inhibition of germination, or of establishment of the seedlings of competing species. Direct poisoning is a possibility. As noted above, the tissues of Rhododendron contain significant quantities of phenols and other potentially toxic chemicals. There is also evidence for the prevention of mycorrhizal development in roots of the seedlings of competing plant species. Research and debate in this field is on-going.[27]

This apparently informative snippet lacks references and a telephone call established that the authorship was unknown to current staff, so verification is not possible. It might simply be another example of the same received wisdom, somewhat extended. I wish we were told where "research … is on-going".

I can find no other candidate precursors for the widely held belief that *R. ponticum* actively poisons British soils and plants. Since these papers are cited in a range of subsequent publications, perhaps with the inhibition factors overstated, slightly but incrementally, we can begin to understand how such misconceptions might have become mainstream, then passed orally, numerous times, from person to person.

CONCLUSIONS

There seems to be no good reason for us to understand from the scientific literature (of which there is little) that *R. maximum* has a chemical allelopathic (poisoning) inhibitory (or fatal) effect upon plants which might attempt to grow under its light-limiting canopy. There is absolutely no reason to consider that *R. ponticum*, to which no similar research has been applied, has an equivalent effect. If such an effect had been demonstrated with *R. maximum*, it would it be reasonable to speculate that similar effects might also apply to the admittedly very closely related *R. ponticum*, and conclusions contrived only after research had provided corroborative data. None of these conditions prevails.

Unless evidence that contradicts current knowledge is forthcoming we must consider that eviction of native floras by either species of *Rhododendron* is caused mainly by shading, and perhaps some other less potent factors, whilst the role of allelopathy can be considered, at best, negligible.

Post rhododendron, a site is inhospitable due to soil/litter modification by rhododendron plus soil biota impoverishment caused by exclusion of plants and establishment of a monoculture, so that restoration of the original plant community will be distressingly slow. To the under informed or misconception driven observer such a site will have the appearance of a place that has been poisoned.

It is my contention that "Rhododendron poisons the soil" is a case of the memetic evolution of a cautious observation into dogmatic factoid. Lots of people have believed and iterated the dogma, but few if any have questioned it or looked for alternative explanations.

Finally

Since rhododendron does plenty of environmental damage under its own steam, it is sensible that we should cause as little harm as possible when we take steps to eradicate it. I would like to recommend the Lever and Mulch method (L&M) for removing rhododendrons[28] as the one that causes least damage and is most likely to permit restoration to proceed as efficiently as possible. A visit to Achnaha Community Wood[29] (mainland Scotland adjacent to the Isle of Mull, NM643456) is recommended. Prior to rhododendron removal in 2004, the site reached the sorry state of inundation. Today, where *R. ponticum* once stifled the local flora and post L&M, bluebells, stitchwort, soft brome, ferns and other typical woodland species are now flourishing (as best they can, considering their circumstances), thanks to the low environmental impact of L&M.

NOTES & REFERENCES

1 The British scientist Richard Dawkins introduced the word "meme" in *The Selfish Gene* (1976) as a basis for discussion of evolutionary principles in explaining the spread of ideas and cultural phenomena. Examples of memes given in the book included melodies, catch-phrases, beliefs (notably religious beliefs), clothing fashion, and the technology of building arches.

2 http://www.plantlife.org.uk/uk/plantlife-campaigning-change-invasive-plants.html

3 http://www.gccv.org.uk/gccv_rhododendron.html

4 http://www.ulsterwildlifetrust.org/Events/newspages/Battle+against+Rhododendron+at+Blessingbourne+Nature+Reserve.htm

5 http://news.scotsman.com/science/Rhodochop-how-martial-arts-will.5907470.jp

6 http://www.nonnativespecies.org/01_Fact_File/06_Old_Fact_Sheets/Rhododendron.cfm?tvk=NBNSYS0000041455

7 A blogger whose 'Aims of the Blog' ironically open with: "O what a complex world we live in, made worse by those who give opinions and spurious analysis."

8 In a comment on John Redwood MP's website in response to Redwood's article *Spare That Rhododendron*, which clearly shows how important the advice of government scientists can be. http://www.johnredwoodsdiary.com/2008/12/10/spare-that-rhododendron/

9 http://www.slef.org.uk/mycorr.html

10 Consider the extreme case of *Cryptothallus mirabilis* – have you ever heard of it, let alone seen it? – a drab, pale, non-green liverwort that lives exclusively below ground. It's difficult to find, difficult to see, difficult to understand and easily overlooked yet ecologically significant. http://en.wikipedia.org/wiki/Cryptothallus

11 The overwhelming majority of soil bacteria and fungi cannot be seen with the eyes, cannot be cultivated for physical and physiological characterisation and, therefore, cannot be directly detected by methods familiar to most humans. Astronomers routinely rely on indirect observations to locate star pairs, black holes, pulsars etc. and never actually see what they know and can prove is there. Similarly, we cannot know what is present in a community of organisms simply by looking for them and counting the ones we are able to recognise with vision. Regrettably, many people prefer to take the simple (simplistic) approach, discounting what cannot be easily detected, but we are mistaken if we think that will ever lead to authentic understanding.

12 In my experience in ecological research, results from laboratory and greenhouse experiments must be treated with extreme caution, even suspicion, because they frequently fail to reflect adequately (if at all) what actually happens in nature.

13 Clinton, B.D. & Vose, J.M. (1996). Effects of *Rhododendron maximum* L. on *Acer rubrum* L. seedling establishment. *Castanea*, 61:1, 38-45 (see note 25).

14 MacArthur, R.H. & Wilson E.O. (2001). *The Theory of Island Biogeography*. Princeton Landmarks in Biology.

15 When rhododendron control is under consideration there are always implications for mammals, birds and other larger animals, some of which even benefit from rhododendron thickets which provide them with protection. These are dealt with elsewhere, e.g. The Lever and Mulch Handbook (see note 28). The main concern here is soil, therefore microbes will be monopolising our attention.

16 It is not pompous to emphasise that mycorrhiza is a difficult concept which requires a lot of head scratching if the uninitiated are to grasp its biology and vital role in world ecology. Mycorrhizologists still have a huge amount yet to learn, but I am doing my best to make what is known accessible to all. Please visit http://www.slef.org.uk/mycorr.html

17 Eelworms.

18 Single celled organisms such as ciliates, flagellates, amoebae and diatoms.

19 Mycorrhiza was 'invented' by coevolution some 450 million or more years ago. Aquatic plants and fungi collaborated and their descendents colonised land as the earliest land plants, which were mycorrhizal. First the molecular evidence predicted that this had occurred and then, later, convincing fossil evidence was discovered in highly detailed fossils found near Rhynie in northeast Scotland.

20 Similar considerations apply to communities compromised by climate change, something that rarely enters the debate. When it does, its importance is grossly underestimated. More often we hear gleeful cries of, "We'll be able to grow vines/olives in Scotland if global warming carries on at this rate!", ignoring the much graver probabilites.

21 Merryweather, J.W. (2007). Planting trees or woodland? An ecologist's perspective. *British Wildlife*, 18:4, 250-258.

22 Allelopathy: a characteristic of some plants, algae, bacteria, coral and fungi by which they produce certain biochemicals that influence the growth and development of other organisms.

23 Other papers that might provide guidance include: Cross, J.R. (1981). The establishment of *Rhododendron ponticum* in the Killarney oakwoods, S.W. Ireland. *Journal of Ecology*, 69, 807-824. [This paper is cited by Lei *et al.* (2002) as indicating inhibition of forest regeneration by *R. ponticum*. I have only the abstract which makes no mention of inhibitory effects, so it is possibly given little emphasis in this paper.] Fuller, R.M. & L. A. Boorman (1977). The spread and development of *Rhododendron ponticum* L. on the dunes at Winterton, Norfolk, in comparison with invasion by *Hippophae rhamnoides* at Salt Fleetby, Lincolnshire. *Biological Conservation* 12: 82–94. [Not seen.]

Clinton, B.D. & J.M. Vose (1996). Effects of *Rhododendron maximum* L. *on Acer rubrum* L. seedling establishment. C*astanea* 61: 38–45.

24 http://www.amjbot.org/cgi/content/abstract/86/11/1597

25 http://coweeta.uga.edu/publications/122.pdf

26 http://cwt33.ecology.uga.edu/publications/pubs_07012004/1568.pdf

27 http://www.countrysideinfo.co.uk/rhododen.htm

28 http://www.leverandmulch.co.uk

29 http://www.morverncommunitywoodlands.org.uk/acw.htm